RHEOLOGY OF PLASTIC MOLDING MIXTURES BASED ON ELECTROMELTED CORUNDUM

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The rheological and structural-mechanical properties of mixtures based on coarse-grained corundum with additives ensuring the production of porous permeable ceramics are considered. It is established that the joint use of different types of additives stabilizes the molding properties of the mixtures, when their composition and moisture vary, and makes it possible to modify the structural-mechanical type and, consequently, the molding conditions and to preserve the configuration of molded samples.

Problems related to environmental protection have not lost their urgency in the past decade. The processes of separation, purification, and concentration of various liquid systems (from sewage to drinking water) are usually based on deep filtration of disperse systems via thin porous membranes. Ceramic filtration elements are widely used at present. The main method for producing these articles is extrusion of plastic mixtures. The mixtures consist of a ceramic filler (which, as a rule, does not become hydrolyzed in water, does not have a sorption complex, and by itself does not form a plastic mixture when mixed with water), an organic or hydroorganic plasticizer in an amount sufficient for producing a plastic mixture, and additives, which determining the service properties of the product. The components differ in their nature, particle size, and habitus and participate in the formation of a plastic mixture structure. Consequently, the molding mixture constitutes a multicomponent complex structured system, whose properties are hard to predict and do not always obey the known regularities.

The purpose of the present study was to investigate the rheological properties of plastified mixtures intended for the production of porous permeable materials. The main component of such batches was coarse-grained electromelted corundum. Soot and fiberglass were used to obtain a porous structure in the material [1 – 4]. In order to decrease the size of interparticle porosity in ceramics, alumina of grade G00 was introduced in the mixture [5] in an amount which does not provide for the densest packing. The plastifier was non-ionogenic PVA.

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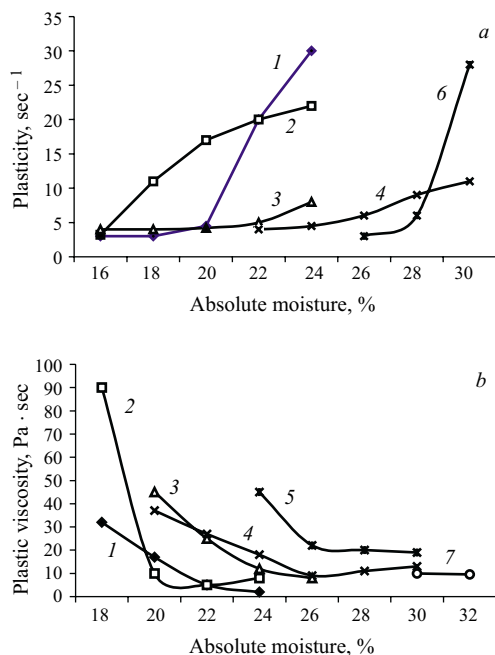
The considered disperse mixtures are characterized by a maximum plastic strength of 200 kPa. The modification of this parameters with increasing moisture is significant: for most considered mixtures a moisture variation by 5% decreases the plastic strength by the factor of 5 – 10. The molding moisture of corundum – alumina – PVA dispersions is around 18%, and it grows significantly when soot is introduced. Mixtures with fiberglass are less prone to an increase in the molding moisture (Table 1).

Fiberglass reinforces mixtures, which facilities the yield limit growth, as the amount of the additive increases. In spite of this, the plastic strength of such mixtures with an equal binder content is lower than that of the soot-containing systems. This is presumably due to the nature of the additive, which determines the type of the interphase contacts and the structure type. Plastic aqueous dispersions contain immobi-

TABLE 1

Mixture	Additive	Additive content, vol. %	Molding moisture, %	Plastic strength, kPa	Moisture, %, of		Yield point, kPa
					expanding limit	yield point	
1	–	–	18.0	47.3	14.7	22.6	1.0
2	Soot	4	22.2	24.2	18.3	26.0	2.0
3	The same	8	25.8	11.7	20.3	29.4	1.6
4	"	12	29.4	5.9	23.5	31.2	1.4
5	"	16	30.0	20.1	25.8	31.7	0.2
6	Fiberglass	4	20.0	14.6	11.8	22.9	0.4
7	The same	8	19.0	18.9	17.4	23.5	1.0
8	"	12	22.5	10.9	15.8	22.6	1.4
9	"	16	18.0	79.3	16.2	21.7	1.6
10	Soot and fiberglass	2 and 2	20.6	27.6	17.5	22.6	1.6
11	The same	4 and 4	20.6	26.5	15.7	24.1	1.8
12	"	4 and 8	20.1	44.5	17.4	24.4	1.7
13	"	8 and 4	24.1	28.1	21.5	25.7	1.7

Fig. 1. Plasticity (*a*) and plastic viscosity (*b*) of mixtures depending on absolute moisture: *1*, *2*, and *3*) fiberglass additive 4, 8, and 16%, respectively; *4*, *5*, *6*, and *7*) soot additive 4, 8, 12, and 16%, respectively.

lized water, which undergoes a rearrangement in the lattice of intermolecular hydrogen bonds under the effect of the surface force field [6].

When the aqueous interlayers are bounded by hydrophobic walls (mixtures with a soot additive), the water molecule dipoles become oriented in parallel with the surface, a negative propping pressure arises, and a solid – solid contact is formed with the condensation type of structure. When the interlayers are limited by hydrophilic surfaces (alumina and fiberglass additives), the water dipoles are oriented perpendicular to the surface and form boundary water layers containing PVA linear molecules, which are horizontally ar-

ranged on the surface of the solid particles [7]. These layers are stable due to the positive component of the propping pressure, which leads to the formation of the coagulation type of structure [8]. The inference on the types of structure agrees well with the obtained data (Tables 1 and 2): elevated plasticity and low yield point and plastic strength are observed in mixtures with fiberglass, whereas mixtures with soot have higher values of the yield point and plastic strength and a low plasticity value.

As the absolute moisture of the dispersions increases, the plasticity of the mixtures with soot grows (Fig. 1) as the content of free plastifier presumably grows, which facilitates an increase in the relative mobility of the system and a decrease in its plastic viscosity, since the structural water has elevated viscosity and thus facilitates an increase in the viscosity of the mixture. In the case of fiberglass, no unique dependence was identified. The plasticity of such mixtures as a rule grows with increasing amount of the binder, since the thickness of the hydrate interlayers increases. However, at the same time the amount of nonengaged free liquid grows as well, which lowers the viscosity. The anisometric fiberglass particles have low-hydration areas, which act as condensation centers. Therefore, with a constant fiberglass content, the yield point with increasing moisture tends to grow, i.e., contacts of the condensation type arise in the system as well, which is accompanied by loss of sedimentation stability.

Fiberglass with its high elasticity modulus (76×10^9 Pa) [9] significantly enhances the elastic deformation of plastic systems, which has a negative effect on the plasticity of mixtures and the preservation of the shape of samples. An increased quantity of soot while maintaining a constant content of the binder provides for a lower level of the elastic and plastic deformation components and a more intense development of the delayed reversible (elastic) component. According to S. P. Nichiporenko, the mixtures usually belong to structural-mechanical types 0 or 3 and can be satisfactorily molded only with a significant content of the plastifier (above 30%).

TABLE 2

Mixture	Deformation modulus, MPa		Plastic viscosity, 10^9 Pa · sec	Volarovich plasticity, 10^{-8} sec^{-1}	Relaxation time, 10^3 sec	Elasticity	Deformation ratio, %		
	elastic	reversible					elastic	reversible	plastic
1	0.44	1.36	5.00	20.0	1.5	0.24	45.5	14.7	39.8
2	0.30	0.75	31.00	6.5	14.5	0.29	66.7	26.7	6.6
3	0.27	11.00	8.20	19.5	31.1	0.02	74.1	1.6	24.1
4	0.29	1.40	13.00	13.5	54.9	0.17	70.2	14.3	15.5
5	0.40	1.20	6.00	3.3	20.0	0.25	50.0	16.7	33.3
6	0.23	5.53	24.00	1.2	159.6	0.04	88.1	3.6	8.3
7	0.26	3.00	6.94	11.2	34.7	0.09	71.1	6.7	22.2
8	0.24	12.00	13.20	1.1	56.1	0.02	3.3	1.7	15.0
9	0.26	6.25	25.30	4.8	116.5	0.04	88.9	3.2	7.9
10	0.40	0.87	7.30	22.9	26.6	0.31	50.0	27.5	27.5
11	0.24	4.80	16.00	11.7	70.0	0.05	83.3	4.5	12.5
12	0.40	2.40	4.70	35.1	13.7	0.14	50.0	8.3	41.7
13	0.47	0.75	6.50	26.2	22.6	0.38	42.7	26.7	30.6

Joint introduction of soot and fiberglass additives makes it possible to stabilize the molding moisture of mixtures in the interval 20 – 24%, whichever additive prevails. A more uniform development of all types of deformation is observed in this case: the elastic deformation component decreases, and the share of the plastic deformation significantly (1.5 – 2 times) increases (see Table 2). The predominance of soot in the complex additive ensures a higher yield point, which grows with increasing amount of the plastifier. When fiberglass quantitatively prevails, the situation is reverse: the yield point is lower and it decreases with increasing content of the binder.

The time of relaxation in the considered systems takes an intermediate position between the values of this parameter for mixtures with fiberglass and mixtures with soot. No definite regularity was established in the variation of this parameter depending on the content of the additive or the binder. However, it should be noted that when the content of the complex additive is over 4%, the time of relaxation is weakly related to the plastifier quantity.

The introduction of additives of various types and with different particle habitus radically changes the molding properties of the plastified mixtures. At the same time, the effect of staple fiber reinforcement is weakly manifested in mixtures based on nonplastic hydrophilic components, and their rheological and structural-mechanical properties mostly depend on the type of the emerging structure, the degree of structure formation, and the quantity of free liquid. The joint use of different additives makes it possible not only to stabilize some properties of the molding mixture, as its composition and moisture vary, but to control the ratio between the deformation components and thus to order the structural-mechanical type and, consequently, the moldability and the molding conditions of the mixture and to preserve the molded sample configuration.

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